FAIRTRADE AFRICA

HASA HORT AGRO SOLUTIONS AGENCIES


# TECHNICAL REPORT

# FOR THE DEVELOPMENT OF STANDARD GREENHOUSE SOLAR DRYERS FOR THE AFRICA FAIRTRADE NETWORK-GIZ FUNDED SOLARED PROJECT

SUBMITTED BY:

HORT AGRO SOLUTION AGENCIES

## ABSTRACT

Preservation of agricultural produce and postharvest practices is one of the central problems faced by developing countries in coffee processing. These stages of operations affect the quality of the beans before milling, subsequent liquor strength, flavors and aromatic value.

The use of solar dryers offers a means that is cheaper convenient, and environmentally friendly to dry coffee. In Kenya, coffee solar dryers have been developed and introduced by different value chain players. However, their technical and economic performance remains unknown. This exercise sought to assess their technical performance. The study was conducted in three coffee societies: Kibirigwi Coffee Society in Kirinyaga County, Kabng'etuny Farmers' Cooperative Society Limited in Kericho County and Kapkiyai Multi-purpose Cooperative Society in Nandi County, Kenya. Additional professional information was obtained from key informants: Mr. Chuaga Kinuthia, a technologist with the Institute of Food Bio Resources Technology at Dedan Kimathi University of Technology and the team at Coffee Research Institute led by Mr. James Minai. Kelvin Muhia, Senior Program Officer at Fairtrade Africa coordinated the teams carrying out this research.

The study analyzed the designs, size, height, construction materials, drying beds, and cost of the solar dryers. A desk review of the performance of coffee solar dryers elsewhere in the world by other coffee producing countries was carried out. The observed drying days relate well with other studies done elsewhere in the world.

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# EXECUTIVE SUMMARY

The project undertook a situational analysis of the 3 drying structures which included a critical appraisal of constraints and opportunities; opportunities analysis focused on opportunities for use of alternative systems of drying coffee and prospects for enhancing cherry quality and labor effectiveness, based on adoption of a new technology.

The methods used were secondary data collection from literature /desk review for each producer organization and focus groups discussions/qualitative interviews with key informants, partners and stakeholders for each producer organization who were identified based on their role in the selected producer organizations.

**Summary of findings and implications**

The project established that solar drying reduces the number of days, costs and labor requirements for coffee drying more specifically:

- The numbers of days used to dry coffee are reduced from an average of 11 days to 4.5 days due to accelerated drying.
- Labor requirements are reduced by 50%.
- Coffee quality is improved.
- Materials used in construction of tables and shelves last longer due to protection from direct sunlight and rainfall.
- Eventual cost of operation reduced.

It is recommended that in order to improve the technical efficiency of solar coffee dryers, designs have to be at least 4.5m high, have a vent at the top to allow the escape of hot air from the dryers, the sides should have net screening for aeration, drying beds be made of up to two shelves for maximum beans holding capacity and fitted with automated temperature and humidity regulation and monitoring systems.

On cost benefit analysis:

**Labor cost**, five casual laborers can work in a single solar dryer (25-30 tonnes) at a wage of Kshs. 500 for six days; =5*500*6 =Kshs.15,000 while sun drying takes minimum of 14 days and 20 staff to dry the same volume of coffee equating to 20*500*14=Kshs.140,000

**Repair & maintenance,** it takes an average of Kshs. 750,000 annually to repairs the drying tables which are often destroyed by direct exposure to sun, rain, rodents and termites. For solar dryers, the cost is reduced to approximately Kshs. 50,000 or less annually.

# INTRODUCTION

## Background and Objectives

Fairtrade Africa sought Hort Agro Solutions Agencies (HASA) as a consultant to work closely with coffee cooperatives, coffee researchers, and academic institutions to tailor make a solar coffee dryer. The aim is to develop a users' manual, develop a standard green house and associated training materials for technicians and dryers.

The following activities and objectives are envisioned to be undertaken.

1. Review the technical performance of three (3) existing solar drier designs in Kirinyaga, Nandi and Kericho counties.
2. Develop a standard coffee solar drier design which will be adopted by producer organizations targeted under the project and develop manuals for design,installation and maintenance of solar dryers.
3. Train 8 technicians to design, install, and maintain the coffee solar dryers.
4. Train 40 Trainers of Trainers on design and maintenance of the coffee dryers.
5. Install two (2) solar dryers once the design has been approved, in a producer organization and one partner organization.

In addition to the above, HASA will offer technical support throughout the project lifecycle to enable the commercialization of the dryers to selected Fairtrade certified producer organizations in Kenya.

## Problem statement

Weather variability is a big challenge facing coffee producer organizations during the drying process. It has a direct effect on coffee quality and labor requirements.

Most of the specialty coffee produced these days is still sun-dried. High rainfall during the harvesting season makes it harder for producers with improper infrastructure to dry their coffee. Wet weather conditions can result in the growth of deleterious fungi, pests and diseases such as borer beetles or rust. High moisture content (i.e., above 11 %) and uneven drying are additional challenges.

Properly dried coffee (with moisture content below 11 percent) may end up fading fast in case it is exposed to high humidity conditions as it becomes highly hygroscopic. This happens when parchment coffee is not evenly dried or as a result of blending of different day-lots with uneven moisture levels. This leads to a decline in shelf life and cup quality due to accelerated chemical deterioration caused by the spread of moisture between the beans.

# STUDY FINDINGS

## Sun drying in coffee processing

Thermal energy plays a key role in processing goods and offering services. It is an essential input for production processes in agricultural businesses, small industries, and commercial services. It is essential for cooking, heating, drying, and smoking and other forms of food processing and preservation. In remote areas, biomass and solar radiation are often the only source of energy available.

In Kenya, coffee farming is primarily found among the small-scale farmers. They lack a direct access to national and international markets. They often sell their coffee beans on the local market at prices far below export price levels. To overcome these challenges, they organize themselves in associations/cooperatives. Evidence shows that association members can generate higher production, benefit from stronger negotiating power and better sales prices from processed coffee sales.

Coffee harvesting is done during the rainy seasons. As a first processing step, coffee beans are sun-dried by spreading them out on the ground without any protection. Due to rainfall interruptions, the drying process can take up to 12 days. However, with climate change leading to warmer weather, the documented period of coffee drying in Kenya is approximately 14 days for open sun drying.

Sun drying takes place when coffee is exposed to the sun and wind and the parchment loses moisture over a certain period of time. This method is economical and effective to produce high quality coffee with good ambient conditions. Unfortunately, most of the harvesting period coincides with unreliable weather conditions to guarantee quality of well-dried coffee. Other challenges faced by factories are cost constraints, lack of adequate infrastructure and over production.

The bulk of energy for sun drying comes from incident solar radiation. This rate, called solar constant, is 1.37kwW per m square at the edge of the atmosphere. The ambient conditions of air relative humidity and atmospheric pressure also influence water loss rates plus other energy inputs such as stirring, loading capacity and airflow. The avoidance of addition of water through contact with rain or overnight dew are paramount management factors. In most factories in Kenya tables with wire meshes and bare earth beneath are used and thus some of these parameters inhibit uniform drying and pose other constraints as previously stated in achieving homogenous product that is taint free and devoid of color defects.

Over-dried parchment has net loss on farmers due to loss in weight and ultimately low returns. Over-dried coffee has moisture content below 5% against the desired 9-11%. This is attributed to long drying period to allow uniform drying process especially during changing weather. It also leads to the de-husking of the parchment to green beans and also opens beans which affects quality. On the contrary, the process of solar drying is highly viable and can be introduced in phases as pilot study and the parchment produced from those particular batches shall give basis of full implementation of such drying methods either in the whole factory, societies and/or cooperatives. This needs to be done through analysis of the beans after milling, liquor quality and market returns.

**Summary of demerits / constraints of sun drying method**

1. Low quality of parchment due to varying temperature levels especially along tropical and subtropical regions
2. Possible contamination of the coffee by dusts, vermin, rodents, birds, insects, leaves and other foreign matter
3. Moisture absorption due to changing weather patterns thus leading to long drying period and compromise in quality
4. Tedious and exhaustive on the workers
5. High labor force required especially during high seasons and rainy seasons
6. Degradation and weathering of the wooden and steel beds and materials by long exposure to the sun, rain, rodents and termites hence need for replacement over time
7. Sagging of beds due to environmental degradation resulting in inhomogeneous drying of the parchment and growth of fungi
8. Materials used to construct drying tables are mostly nonfood grade
9. Spillages of the parchment due to sagging meshes
10. Growth of shrubs, weeds and grass along and underneath the tables that breed rodents and insects thus requiring constant weeding and spraying which is source of contamination
11. Fungal growth especially OTA-mycotoxin derived from coffee chain such as temperature, moisture, injury or microorganism from filed or processing stages

## Solar drying in coffee processing

Solar drying is a possible replacement for sun drying or for standard dehydration processes. Farmer associations and factories can afford to establish solar dryers to produce higher quality product.

The approach is two-fold along the coffee value chain. Freshly pulped coffee has a moisture content (MC) of about 55%, which has to be reduced by drying to 11%. In the first drying period, the humidity of coffee beans is reduced to 25%. The solar dryer shelter

prevents the coffee beans from getting wet from the rain. It improves the drying process by filtering UV radiation, concentrating heat, reducing the relative humidity of the air, and thus drying the beans with constant and natural ventilation. The drying time is reduced to 2-3 days.

11% is the ideal level of moisture content required for proper storage, hulling and roasting. In Kenya, sun drying is predominantly used by co-operatives whereby coffee is spread on wire mesh tables for several days (normally about 14 days), until fully dry. When it rains, the coffee is covered with polythene sheets to avoid re-wetting.

**Summary of advantages of solar drying:**

1. The higher temperature, movement of air and lower humidity, increases the rate of drying
2. Produce is enclosed in the dryer and therefore protected from dust, insects, birds and animals
3. The higher temperature deters insects and the faster drying rate reduces the risk of spoilage by microorganisms
4. The higher drying rate also gives a higher throughput of food and hence a smaller drying area (roughly 1/3)
5. The dryers are water proof and the produce does not therefore need to be moved when it rains.
6. Dryers can be constructed from locally available materials and are relatively low cost

## RESULT FINDINGS AND ANALYSIS

This section analyses and compares the drying period, cupping and milling aspect of solar dried and sun-dried coffee.

### Drying period

The study findings establish the coffee drying period as approximately 14 -21 days for open sun drying. In comparison, the drying period in a solar dryer is 50% lower, at 7-10 days.

According to a 1982 study by the Coffee Research Institute (formerly CRF) the best drying raised tents height should be approximately 1.5m. This achieved a reduction in the number of days required to dry by between 7-11 days depending on the weather (Kenya Coffee, November 1982, pg. 258 -260).

Researchers at Coffee Research Institute acknowledge the need to document the period that it would take with improved designs and even recommend further improvements from the experiments done in the past.

## Cupping quality

In terms of cupping, solar drying produces better quality coffee than open sun drying. Solar dried coffee tends to be sugary, caramel-like and aromatic in flavor due to controlled and a uniform drying process. Sun dried coffee on the other hand tends to have a woody flavor due to a long drying process or over drying. The better quality of sun-dried coffee is enhanced by the following factors:

i. There is less likelihood of re-wetting. Rain can cause severe damage to the bean quality particularly as it nears final drying
ii. The water that condenses on the polythene that covers drying beans overnight also easily falls back to the parchment causing re-wetting
iii. The white stage in coffee drying is highly prone to loss of quality; the practice of covering the parchment at that stage usually leads to quality deterioration. In a dryer, it the parchment can be left open throughout the day. This can lead to improved quality

Despite the above, researchers from Coffee Research Institute still acknowledged the need for data to be collected to verify the fact that solar drying produces better quality coffee.

## Milling aspect

On the milling aspect, sun dried coffee when milled usually achieves classes of 4 plus while that of solar-dried can achieve classes of 3 plus. This is dependent on the final moisture content of the beans. It is therefore important to monitor the moisture content especially from medium black stage to the hard-black stage. A well calibrated moisture meter needs to be at hand to avoid over-drying.

Mr.Chwagga, from Dedan Kimathi University of Technology also noted that with proper aerated dryers, the cup has major notes characterized by fruity and floral notes; more like wine. However, with no aeration, the cups are flat and lacking in character. While coffees dried outside are also characterized by floral and fruity notes, these are magnified once the sun is controlled via solarized drying. He further acknowledged that raw beans are normally affected if drying is not properly monitored. In enclosed solarized drying, the beans are characterized by a faded color due to speed drying. In comparison, a combination of outside and solarized drying allows aeration, giving the beans a greyish-green color when drying is properly monitored.

In Nguguine Factory, interviews with some farmers and the chairman of the factory provided further thoughts on solarized dryers. Mr. Samson Mureithi Muriuki who is the assistant liqourer at Central Coffee Mills as well as former Head of Quality at Dormans Coffee further provided views on the attributes of the dryers.

## Conversions Rate

The conversion rate: sun-dried parchment is about 1:7 while that of solar-dried parchment is 1:5. This means the solar-dried coffee is able to achieve clean coffee after milling with less volume compared to sun-drying. On the milling ratio, due to controlled drying processes in solar dryers, less loss is incurred compared to sun-dried coffee. The following table shows outputs of the two dried coffee types.

| Parchment Quality | solar dried (enclosed) | Sun Dried (Open) |
|---|---|---|
| **P1** | 17%, | 19-21%, |
| **P2** | 22%, | 24-26%, |
| **P3** | 28% | 30-33% |
| **Plight** | 33%. | 35-40%. |

(*P1 represent parchment of high value and Plights represent low value milled coffee.*)

Mr. Samson mentioned that a lower number of lower grades means more premium quality and consequently high market value. It therefore means that solar-dried coffee has huge returns for farmers. All the same, this still requires further analysis.

Correspondence with Raphael Prime who is also a former Head of Quality at Dormans which had links with Coffee Management Services was key in the above findings. He explained how they have managed to study and install some of the best solar dryers in private firms and some factories and how efficient and economical they have been when well controlled and monitored. He emphasized the need to ensure better returns for farmers.

Solar-drying has huge potential if more funding on research and rolling out can be applied. These dryers can be installed in phases and proper documentation of information done. This will ensure proper traceability from farm to cup either in domestic or overseas markets, hence yielding more and consistent returns for farmers.

## Sun drying versus solar drying

Solar drying is a possible replacement for sun drying or for standard dehydration processes. In terms of sun drying, solar drying is competing with an approach that is deeply entrenched in the way of life for most potential users. Sun drying is by no means a perfect process with problems arising due to potential contamination of the produce, variability in drying times, rain damage and so on. Despite the challenges posed by this form of drying, the adoption of solar drying which is more beneficial remains low for the following reasons:

- Solar dryers have often been too expensive or initial investment capital/ loan facilities are unavailable
- Solar dryers have often been too complicated or poor training of local entrepreneurs and technicians was provided
- Solar dryers have often required very big changes from traditional methods
- Solar dryers have not been built for long term use
- There is a lack of incentive to improve the quality of the product. People are willing to pay nearly the same amount for discolored or damaged produce. Hence, there is no incentive for producers to risk higher amounts of money in a dryer when there is not a great return.

When comparing solar drying to the conventional dehydration processes a new range of issues arises. These include:

- Solar dryers must provide the equivalent performance to that of the conventional processes in terms of capacity, labor input, the quality of the final product, the total drying costs and reliability.
- A backup heating system should be installed to ensure drying during the critical periods when the weather is bad.

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

1. Homogenous coffee drying process can be achieved by controlled temperatures within the solar dryers
2. A solar dryer ensures that coffee parchments are free from possible environmental contaminants such as dusts, insects, and foreign matter
3. Solar dryers accelerate the drying process of coffee parchment
4. Hygienic processing of coffee can be achieved with the use food grade materials and shelves which could be practically impossible outside solar dryers
5. Materials used to construct the tables and shelves will last longer due to protection from direct sunlight and rainfall by the solar dryers
6. Use of solar dryers requires less labor force and work intensiveness
7. Coffee that is under dried when milled becomes clumpy and incase it is taken to auction; it attracts very few buyers or low prices due to its nature.
8. The floor in solar dryers is usually cemented hence less likely for moisture drop or rise
9. Solar dryers are free form wind, rain, fog and mist
10. Solar dryers can be maximized by having two shelves within one greenhouse hence economical on space

## Recommendations

1. The height of the solar dryers should be at least 4.5m high
2. The dryers should have a vent at the top to allow the escape of hot air
3. The sides should have net screening for aeration
4. Dryers should be fitted with automated temperature and humidity regulation and monitoring systems
5. The floors should be cemented for ease of hygiene maintenance and prevention of rapid moisture drops or rise.
6. The numbers of drying beds/shelves need to be 2 to ensure maximum bean holding capacity and efficient utilization of space and proper drying. In addition, the first shelf should not be too low.

A fan was recommended by CRI, but it was noted that for it to be adoptable among producer organizations, a simple design be recommended for use and maintenance. An alternative design with shade nets to allow the escape of hot air was recommended to regulate the temperatures.

## REFERENCES:


1. A field survey on coffee beans drying methods of Indonesian smallholder farmers: https://iopscience.iop.org/article/10.1088/1757-899X/237/1/012037/pdf
2. Coffee Processing with Solar Dryers Peru: Deutsche Gesellschaft für International Zusammenarbeit- Poverty-oriented Basic Energy Services (HERA) and European Union Energy Initiative Partnership Dialogue Facility.
3. EKECHUKWU, O.V.a.N.B.: Review of solar-energy drying systems II: an overview of solar drying technology, Energy Conversion & Management 40 pp 615-655, Pergamon (1999).
4. International Journal of Innovative Technology and Exploring Engineering (IJITEE)ISSN: 2278-3075, Volume-9 Issue-4, February2020

# ANNEXES

## Responses from Christopher Muriithi

| | | |
|---|---|---|
| **Name of Respondent** | | Christopher Muriithi |
| **Position** | | Acting factory manager |
| **Cell Phone** | | 726254975 |
| **Producer Organization** | | Kibirigwi farmers' cooperative society limited –Nguguine factory |
| **Date** | | 28/08/2020 |
| **County** | | Kirinyaga |
| **Q1:** | **What is the general overview of your organization?** | 1. Owned by small scale farmers. |
| | | 2. Fairtrade certified. Have received support by Fairtrade Africa. |
| **Q2:** | **When was the solar dryer constructed?** | The dryer have been use for the last 3 seasons since 2018. |
| **Q3:** | **Out of the total volume what percentage is dried through the solar dryer?** | Approximately one third of the total produce is dried through the solar dryer. |
| **Q5:** | **How has the use of dryer impacted the factory operations?** | 1. The drying period have been reduced an average of 12 days to an average of 7 days. |
| | | 2. The number of casual labourers used in the drying process has been reduced by one third. |
| | | 3. The drying period in terms of months have been reduced by at least one month. |
| | | 4. The drying process is continuous irrespective of the prevailing weather conditions i.e. even if it is cloudy and raining. |
| **Q6:** | **Have the use of the solar dryer improved quality?** | We have not analysed the quality as all the coffee either dried outside or in the solar dryer are delivered to the millers as one batch. |
| **Q7:** | **What challenges have you faced in the use of the solar dryer?** | 1. Sometimes the temperatures are too high hampering operations in the dryer. |
| | | 2. The solar dryer is unable to handle all the quantities of the produce. |
| | | 3. The metal stands are affected by rust. |
| **Q8:** | **Are you aware of the best conditions in terms of temperatures and humidity ideal for coffee drying?** | Not aware and therefore just put the coffee inside and only check the moisture content on and off until the desired moisture content is achieved. |
| **Q9:** | **Do you have mechanisms to control the temperature and humidity in the solar dryer?** | No. We use the body reactions, if it's too hot we open the doors. |
| **Q 10:** | **Do you have any recommendations in regard to design of the solar dryer?** | 1. The beds need to be made of metal as the current ones made of wood are prone to termites and other damages. |
| | | 2. The ground need to be made of concrete as currently is earthen and too dusty. |
| | | 3. There is need to have vents which allow free movement of air. |
| | | 4. Need to have a water collection and storage system for the water |

*Figure 1 Nguguine Factory KII Response*

## Responses from Geoffrey Koech

| | | |
|---|---|---|
| **Name of Respondent** | | Geoffrey Koech |
| **Position** | | Factory manager |
| **Cell Phone** | | |
| **Producer organization** | | Kabngetuny farmers' cooperative society limited |
| **Date** | | 29/08/2020 |
| **County** | | Kericho |
| **Q1:** | **What is the general overview of your organization?** | 1. Owned by 1,324 registered small scale farmers: 988 men and 336 women. |
| | | 2. Managed by a CEO through a 9 member committee with 3 supervisory members. |
| | | 3. It is Fairtrade certified, which have given support in trainings on good agricultural practices, climate change and installation of biogas digesters. |
| **Q2:** | **When was the solar dryer constructed?** | The dryer have been use for the last 3 seasons since 2017.Constructed through the support of Fairtrade. |
| **Q3:** | **Out of the total volume what percentage is dried through the solar dryer?** | Approximately a quarter of the total produce is dried through the solar dryer while the rest is dried outside. |
| **Q5:** | **How has the use of dryer impacted the factory operations?** | 1. The drying period have been reduced an average of 10 days to an average of 7 days. |
| | | 2. The numbers of casual labourers used in the drying process have been reduced. However there are no records indicating the change in labour requirements. |
| | | 3. Initially the coffee drying process having been running from October to late March, but since the introduction of the solar dryer the process ends sometimes in early February. |
| | | 4. The coffee drying starts in the months of October and November which are characterized by heavy rains. This puts the management on high alert to cover the |
| **Q6:** | **Have the use of the solar dryer improved quality?** | No information available since all the coffee, whether dried inside or outside is mixed and delivered as a single batch to the millers. |
| **Q7:** | **What challenges have you faced in the use of the solar dryer?** | 1. Sometimes the temperatures are too high hampering operations in the dryer. This reduces the working hours. |
| | | 2. The solar dryer only handles a small quantity of the produce. |
| **Q8:** | **Are you aware of the best conditions in terms of temperatures and humidity ideal for coffee drying?** | No, have never occurred to us and drying is just drying. |
| **Q9:** | **Do you have mechanisms to control the temperature and humidity in the solar dryer?** | No, not sure of how temperatures and humidity is as we do not have devices to determine them nor control them. |
| **Q10:** | **Do you have any recommendations in regard to design of the solar dryer?** | 1. There is need to make the beds in the dryer in layers of 3 to accommodate more produce as opposed to the current on which is only one layer. |
| | | 2. There is need to have a concrete floor which is easy to clean. |

*Figure 2 Kabng'etuny Farmers Coop Society Ltd. KII Réponse*

## Responses from Peter Koech

| | | |
|---|---|---|
| **Name of Respondent** | | **Peter Koech** |
| **Position** | | **Chief executive officer** |
| **Cell Phone** | | |
| **Producer organization** | | **Kapkiyai multi-purpose cooperative society** |
| **Date** | | **29/08/2020** |
| **Q1:** | **What is the general overview of your organization?** | 1. Owned by 645 small scale farmers.<br>2. Fairtrade certified. An office block being built, have an incubator and 135 women have benefited with biogas digesters which have increased coffee<br>3. Average production per bush is 2.1 Kgs. |
| **Q2:** | **When was the solar dryer constructed?** | The dryer have been use for the last 3 seasons since 2017. |
| **Q3:** | **Out of the total volume what percentage is dried through the solar dryer?** | Approximately one fifth of the total produce is dried through the solar dryer. |
| **Q5:** | **How has the use of dryer impacted the factory operations?** | 1. The drying period have been reduced an average of 7-10 days to an average of 5-7 days.<br>2. The number of casual labourers used in the drying process has been reduced. In 2018/2019 a total of 14 casuals were hired per day while in 2019/2020 a total<br>3. Less number of months is spent drying coffee and therefore reducing the operational costs. However these have not been quantified. The process is finished<br>4. The need to cover and uncover the coffee in the beds outside is no longer |
| **Q6:** | **Have the use of the solar dryer improved quality?** | This cannot be confirmed as all the coffee is delivered as a single batch weather dried outside or the solar dryer. |
| **Q7:** | **What challenges have you faced in the use of the solar dryer?** | 1. During the dry months the temperatures inside the dryer are too high<br>2. The solar dryer is small and unable to handle all the quantities of the produce.<br>3. The dryer is sometimes destroyed by strong winds experienced from time to |
| **Q8:** | **Are you aware of the best conditions in terms of temperatures and humidity ideal for coffee drying?** | No, as long as the coffee dries to our desired moisture content we are good to go. |
| **Q9:** | **Do you have mechanisms to control the temperature and humidity in the solar dryer?** | No. as long as it is hot and humid to the worker, and then it is. |
| **Q10:** | **Do you have any recommendations in regard to design of the solar dryer?** | 1. There is need to put a temperature and humidity control mechanisms that fits the temperatures and humidity required to dry coffee.<br>2. There is need to have a concentrate floor as opposed to an earthen floor which makes cleaning difficult. |

Responses from Mr. James Minai-Cri, Mr. Chwagga -Dkuat and key stakeholders

Solarised questionaire

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Development of a Standard Greenhouse Solar Drier for the Solared Coffee.

1. Does the use of solar dryers reduce drying time of coffee?

If yes by how long. How long does it take to dry outside and how long inside? Kindly give your comments and Observation

It depends on the kind of solar driers used. If there is aeration in the driers, the drying time is twice longer than drying coffee outside while if no aeration, the drying time is reduced by a half (drying can be done in 10days)

2. How is quality affected by drying coffee outside and in the solar dryers in terms of:

a) Cupping

With proper aerated dryers, the cup has major notes characterized by fruits and floral notes more like wine. However, with no aeration, the cups are flat and commonish lacking any character. The coffees dried outside are also characterized by floral and fruity notes but once the sun is controlled via solarized drying, the notes are magnified.

a) Milling losses

Drying has no effect on the milling losses of coffee.

b) Bean cleanliness

Bean cleanliness is not affected by drying

c) Raw beans and cup quality

Raw beans are normally affected if drying is not properly monitored. For enclosed solarized drying, the beans are characterized by faded beans, due to speed drying while outside drying and in solarized drying that allow aeration, the beans are greyish green in color when drying is properly monitored.

d) If parchment is cracked due to heat, what is the comparative effect on bean cracking and change of colour for solar drying

Again parchment cracking is dependent on the discipline of drying... Fast drying characterized by non-enclosed solarized beds leads to cracked and open parchment.

However, in a well-controlled drying, the parchment ought to be intact

e) Kindly comment on the recommended process of coffee drying and how it would change by using solar drier as compared to open sun drying.

Controlled form of drying is the best. If a farmer is able to control the type of the wavelengths reaching the coffee, then the quality of the coffee improves. This form of drying is supported by proper aeration of the dryer atmosphere to minimize the humidity inside.

3. Based on your research and experience how does temperature and humidity affect the drying period and quality

Research needs to be done on this area. Based on my experience, the temperatures in aerated dryers are normal while those in enclosed dryers are very high normally above 40 degrees (no research done to determine this).

Development of a Standard Greenhouse Solar Drier for the Solared Coffee.

3. What are the ideal temperatures and humidity ranges for the best quality.

Research needs to be done on this area to have the accurate figures which in our institution we haven't done.

4. Does use of solar dryers reduce labor requirements?

Yes. Labor is reduced especially where the management would have required personnel to cover and uncover the coffee against harsh environment (either too much sun or rain), in solarized drying the coffee is protected against harsh weather.

6. Are there environmental, social, economic challenges associated with the use of solar dryers? If yes what are the and how can they be mitigated.

One of the major challenges is extreme windy weathers or hail stones rains that destroy the dryers

Another challenge is theft of coffees; when coffees are inside the dryer, they still need to be protected against theft.

Once a farmer adopts the solarized drying methods, there's a sizeable loss of employment as a result

The initial cost of the solarized dryers may be high for the farmers in comparison to the returns of the coffee.

7. We are proposing this design for adoption by coffee producer organizations what are your comments

A research needs to be done to investigate any effects on the cup quality.

**QUALITY ASSUARANCE**

There is need to test the cup quality of coffee dried in the dryers vis-à-vis the one dried in open sun. This will help in setting the standard drying temperatures and humidity that result in the best quality of coffee.

Kindly give your opinion / recommendation based on your research and liquor experience

No research done on this area in my case and hence I recommend one to be conducted in order to investigate any changes.

The comparative Advantage of using solar dryer

In well aerated dryers, there have been claims on improvement of quality, but this needs to be affirmed in our Kenyan coffees.

## Development of a standard greenhouse solar drier for the Solared coffee project.

1. Does the use of solar dryers reduce drying time of coffee?
If yes by how long. How long does it take to dry outside and how long inside? Kindly give your comments and Observation

Yes it does. Documented evidence from a study conducted using some raised tents (approx. 1.5m) in 1982 at Coffee Research Institute (formerly CRF), showed a reduction in the number of days by between 7-11 days depending on the weather (Kenya Coffee, November 1982, pg 258 - 260).

The drying period were
a) Open sun drying – approximately 14 -21 days
b) Drying in the dryer - 7-10 days

However, with the climate change leading to warmer weather, the documented period of coffee drying in Kenya is approximately 14 days for open sun drying

There is therefore need to document the period that it would take with improved designs and even recommend further improvements from the experiments done in the past

2. How is quality affected by drying coffee outside and in the solar dryers in terms of:
    a) Cupping

The general observation is that solar drying produces better quality coffee particularly because;

i. There is less likelihood of re-wetting. Rain can cause severe damage to the bean quality particularly as it nears final drying.
ii. The water that condenses on the nylex overnight also easily falls back to the parchment causing re-wetting
iii. The white stage in coffee drying is usually very prone to loss in quality. The practice of covering the parchment at that stage usually leads to quality deterioration. In a dryer, it the parchment can be left open throughout the day. This can leads to improved quality

However data needs to be collected to verify the fact that solar drying produces better quality coffee

a) Milling losses

This depends more on the final moisture content of the beans. It is therefore important to monitor the moisture content especially from medium black stage to the hard black stage. A well calibrated moisture meter needs to be at hand to avoid over-drying

Development of a standard greenhouse solar drier for the Solared coffee project.

a) Bean cleanliness

Solar drying gives relatively cleaner beans since there is less fading

b) Raw beans and cup quality

The general observation on the quality of raw beans and the cup using the solar driers is that there is improved quality of both. However this is one area that requires data to be collected and analyzed to authenticate this general observation

c) If parchment is cracked due to heat, what is the comparative effect on bean cracking and change of colour for solar drying

Ideally, coffee should not be strongly irradiated especially at white stage so as to avoid cracking. The esters essential for desirable bean colour are also formed at this stage and strong irradiation would break them down to complex products thus affecting the final bean colour

Although not documented, the expectation would be that – in a solar dryer, the effects would be ameliorated by the evenness of temperature thus causing less damage

d) Kindly comment on the recommended process of coffee drying and how it would change by using solar drier as compared to open sun drying

Of essence to note is that in open sun drying, the parchment needs to be covered at night and in adverse weather. However in a solar drier, this won't be necessary. Consequently, better quality coffee can be achieved since the parchment can dispel off smells arising from moistness that is usually trapped when the parchment is covered.

3. Based on your research and experience how does temperature and humidity affect the drying period and quality

i. Higher temperatures will lower the drying period.
ii. Low RH will also lower the drying period
iii. However extreme temperatures, above 40$^{o}$C destroy the quality of coffee. The damage caused by over-heating depends on the moisture content of the parchment, the temperature and the time coffee is exposed to over-heating. For instance, a sudden high increase of temperature to 60$^{o}$C for a few minutes may be less harmful than 50$^{o}$C for several hours

Development of a standard greenhouse solar drier for the Solared coffee project.

3. What are the ideal temperatures and humidity ranges for the best quality.

i. The ideal drying temperatures would be approximately 20°C and 38°C. However, it's important to note that the speed at which coffee picks up heat and consequently the speed at which temperature must be lowered to avoid damage to the coffee will depend on the features of the dryer and the moisture levels of the incoming coffees. Further, natural conditions may cause the temperatures to be lower than 20°C in the dyer. In which case, the dryer should be closed to raise the temperature

ii. The ideal RH is difficult to determine during drying because of the variations in the moisture content of the parchment being dried at different stages

iii. However, it's important to bear in mind that for coffee to be fully dry, a RH of 61% is necessary. If the RH is higher than that, the parchment may not release the water in it. This may cause the parchment not to attain the correct moisture content even when kept in the dryer.

4. Does use of solar dryers reduce labor requirements?
If yes but what margins per unit volume.

Yes it does.

The study in 1982 indicated that that system of drying coffee reduced the amount of labor employed because;

i. Opening and covering of parchment during adverse weather and at night is eliminated

ii. The acceleration of drying by 7-11 days means less time needed hence saving the labor that would have been employed

iii. Skin drying can be done together with other drying stages in the same tent thus eliminating the labor needed to move the parchment to final drying tables

iv. Further, sorting can be done even during the rainy days hence increasing the efficiency of labor employed

This implies labour efficiency can be improved by 40-50%

6. Are there environmental, social, economic challenges associated with the use of solar dryers? If yes what are the and how can they be mitigated.

There are no documented nor factual environmental, social or economic challenges associated with solar dryers.

The only observed challenge is the extreme heating in dryers without heat vents. This can be easily overcome by having some open part in the roof

Development of a standard greenhouse solar drier for the Solared coffee project.

7. We are proposing this design for adoption by coffee producer organizations what are your comments.

i. Any design that does not have a heat vent may lead to overheating of coffee beyond the recommended 38$^{o}$C. The design that allows heat to dissipate as recommended by HASA is thus a good model and we recommend the design to be implemented. This also prevents condensation of the water at the roof which may then drop, re-wet the coffee and cause ageing of the coffee and deterioration of quality.

ii. Whereas the idea of having several layers of coffee parchment trays is good in reducing the space needed in the factories, consideration needs to be made not to have the first shelf too low – may lead to coffee picking an earthy flavour or having the third shelf too high for workers to do the turning and sorting which may have adverse effects on the quality of coffee. There is also need to test the effect on drying time for several layers and the effect on quality for the lower layer that may be less than a meter from the ground

iii. We thus recommend two layers at (1meter and approx. 1.4 m) for now until further research work is done to test all the other parameters that may affect the coffee quality

iv. Apart from the net screening at the sides for aeration, flaps that open up from below for up to a meter or so will be necessary. This allows air to the dryer to be opened up when it is hot and closed when it is rainy or relatively cold. That ventilation from below (up to approx. I meter from down) will allow air movements on hot days but can be covered in adverse weather and at night.

v. The idea of fitting the dryer with an automated temperature and humidity regulation and monitoring systems may be good. But given that this dryer is meant to be commercialised in future, and knowing that our target group will be the coffee farming community, we should endeavour to be near natural as possible. It is thus our opinion that an automated temperature regulation may not be ideal for the intended future commercialization. However, this discussion can be further extended between CRI engineer and the HASA engineer

vi. There is need to install a data logger in the solar dryer to monitor and record the temperature and the relative humidity. This will enable the CRI team to correlate any variations in the data expected from the experiment. Note that is for monitoring the dryer conditions and to assist in informing any necessary adjustments in the designs for future commercialization.

vii. A Thermometer also needs to be installed in the dryer to give a casual check on the temperature at particular point in time. This can be part of the commercialised dryers

viii. Provide a thermometer to measure the ambient temperatures for comparison with the temperatures in the solar dryers

Solarised questionaire

Development of a standard greenhouse solar drier for the Solared coffee project.

i. The dryer should be constructed in a direction that does trap air to avoid damage of the dryer.
ii. There is need to do further research on these solar dryers. This is because several parameters needs to be considered and their impact on quality determined. These may include the effect of lower level of trays on quality, the effects of several tiers on drying time and the effects of increased capacity on cost of processing among others.
iii. Further improvements or modifications may also be recommended in the course of the project implementation or after further research before the commercialization phase

**QUALITY ASSUARANCE**

There is need to test the cup quality of coffee dried in the dryers vis-à-vis the one dried in open sun. This will help in setting the standard drying temperatures and humidity that results in the best quality of coffee.

Kindly give your opinion / recommendation based on your research and liquor experience

i. The basics about temperature and humidity are known. Further settings can be informed by the data logger recommended above
ii. The experiment for testing the cup quality will be set as per the KALRO-RI standards, data collected analysed and recommendations made accordingly

The comparative Advantage of using solar dryer

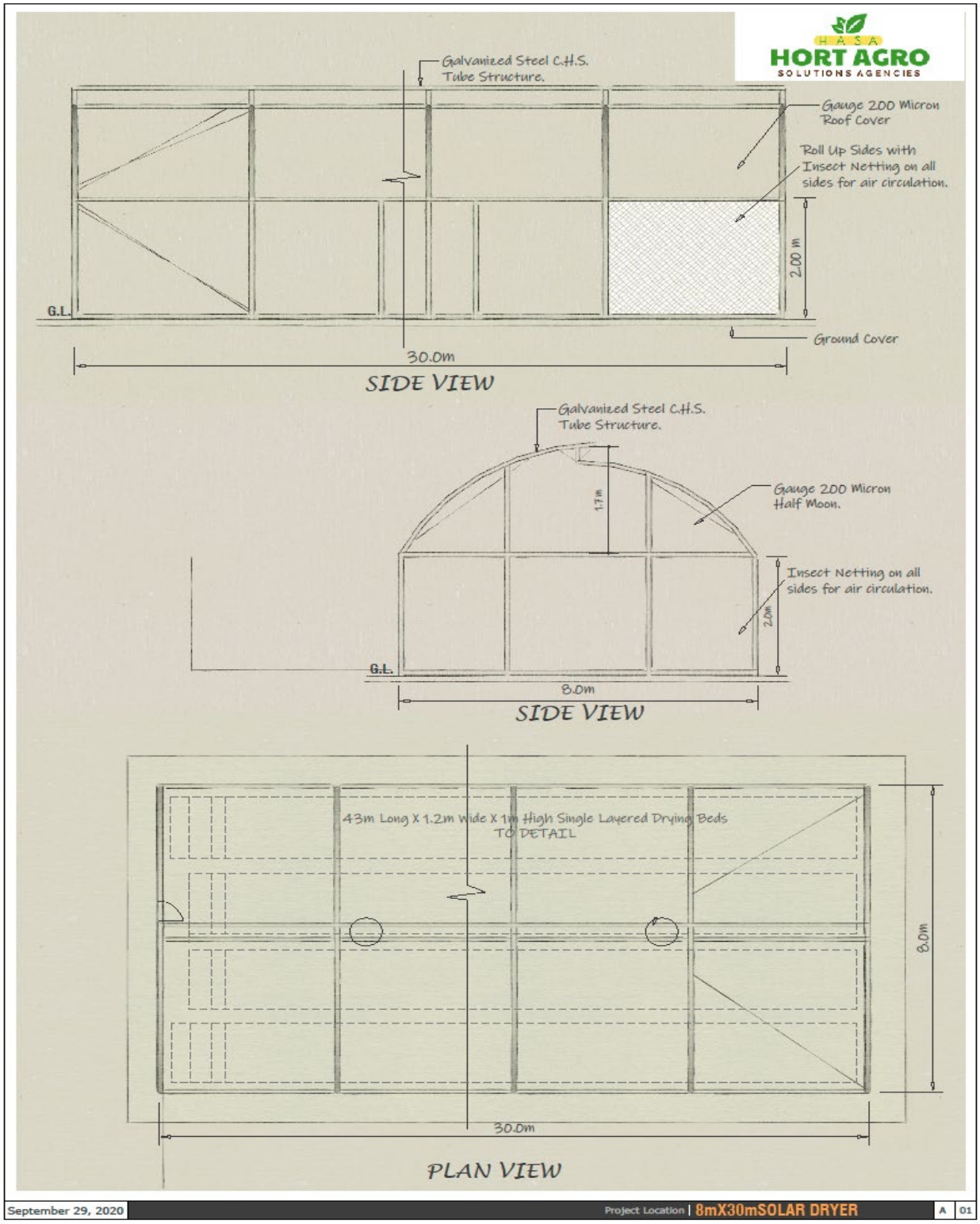
i. Reduction in the number of days needed to dry the parchment
ii. Reduction in the cost of labour occasioned by the reduction in the number of days
iii. Increased labour efficiency arising from better utilization of labour employed since the workers can still work in the greenhouse whenever there is rain during the drying season
iv. Improved quality due to better drying conditions

## Sample pictures of the solar dryer interior and raised benches

## BILL OF QUANTITIES

| S/n | Description | Unit price (Kshs.) | Quantity | Subtotal (Kshs.) | Total | Total budget (Kshs.) |
|---|---|---|---|---|---|---|
| 1 | GI Metal pipes 1.5” | 1,800 | 100 | 180,000 | 2 | 360,000 |
| 2 | GI Metal pipes 1” | 1,500 | 100 | 150,000 | 2 | 300,000 |
| 3 | P.E. Film (UV treated) | 12,000 | 10 | 120,000 | 2 | 240,000 |
| 4 | Digital Thermometer | 5,400 | 2 | 10,800 | 2 | 21,600 |
| 5 | Locking profile | 700 | 100 | 70,000 | 2 | 140,000 |
| 6 | Mesh (Metallic light gauge) | 10,000 | 10 | 100,000 | 2 | 200,000 |
| 7 | Mesh (Plastic) | 11,500 | 10 | 115,000 | 2 | 230,000 |
| 8 | Cement | 700 | 4 | 2,800 | 2 | 5,600 |
| 9 | Ballast | 400 | 3 | 1,200 | 2 | 2,400 |
| 10 | Sand | 300 | 3 | 900 | 2 | 1,800 |
| 11 | Welding rods | 1,800 | 2 | 3,600 | 2 | 7,200 |
| 12 | Rivets | 1,596 | 1 | 1,596 | 2 | 3,192 |
| 13 | Paint | 2,500 | 2 | 5,000 | 2 | 10,000 |
| 14 | Labor and logistics | 138,000 | 1 | 138,000 | 2 | 276,000 |
| | **Totals** | | | **898,896.00** | | **1,797,792.00** |

# DESIGN


HASA
HORT AGRO
SOLUTIONS AGENCIES
Galvanized Steel C.H.S. Tube Structure.
Gauge 200 Micron Roof Cover
Roll Up Sides with Insect Netting on all sides for air circulation.
2.00 m
G.L.
Ground Cover
30.0m
SIDE VIEW
Galvanized Steel C.H.S. Tube Structure.
1.7m
Gauge 200 Micron Half Moon.
Insect Netting on all sides for air circulation.
2.0m
G.L.
8.0m
SIDE VIEW
43m Long X 1.2m Wide X 1m High Single Layered Drying Beds TO DETAIL
8.0m
30.0m
PLAN VIEW
September 29, 2020
Project Location | 8mX30mSOLAR DRYER
A
01

**NB**: The roll up insect netting will be fitted on either of the two sides depending on the wind direction at the specific site.